Claims

1. A thermal microelectrical mechanical actuator, comprising:

a planar substrate with first and second anchors secured thereto;

an in-plane shuttle floating on the substrate for motion parallel to the planar substrate;

plural elongated thermal half-beams that each have a base end secured to the first anchor and a distal end secured to the in-plane shuttle;

plural elongated thermal half-beams that each have a base end secured to the second anchor and a distal end secured to the in-plane shuttle; and

electrical couplings to direct electrical current through the thermal half beams via the anchors to impart thermal expansion of the thermal half-beams and motion of their distal ends.

2. The actuator of claim 1 in which the in-plane shuttle has a length and two sides along its length and the first and second anchors are positioned to one side of the in-plane shuttle.

3. The actuator of claim 2 further including an elongate floating cold beam that is transverse to the length of the in-plane shuttle, the floating cold beam being coupled at one end to the in-plane shuttle and at another end to the substrate.

4. The actuator of claim 2 in which the thermal half-beams have more mass near their centers than at their ends.

5. The actuator of claim 4 in which the thermal half-beams are wider near their centers than at their ends.

6. The actuator of claim 1 in which each thermal half-beam is secured between its anchor and the in-plane shuttle at a non-orthogonal bias angle.

7. The actuator of claim 1 in which the in-plane shuttle is generally in-plane with the thermal half beams.

8. The actuator of claim 1 further including an alignment structure that is secured to the substrate and slidably engages the in-plane shuttle to constrain it to move generally parallel to the substrate.

9. The actuator of claim 1 in which the in-plane shuttle further includes one or more dimple bearings that project from the in-plane shuttle toward the substrate.

10. The actuator of claim 1 in which the thermal half-beams are formed of a material with a positive thermal coefficient of expansion.

11. The actuator of claim 1 in which the thermal half-beams have more mass near their centers than at their ends.

12. The actuator of claim 1 in which the thermal half-beams are tapered from their centers toward their ends.

13. The actuator of claim 1 in which the thermal half-beams have in-plane widths that are tapered from the centers of the thermal half-beams toward their ends.

14. The actuator of claim 13 in which the centers of the thermal half-beams have widths that are about twice those of the ends of the thermal half-beams.

15. The actuator of claim 1 in which the in-plane shuttle has a length and two sides along its length and the first and second anchors are positioned on opposite sides of the in-plane shuttle and the thermal half-beams have more mass near their centers than at their ends.

16. The actuator of claim 15 in which the thermal half-beams are wider near their centers than at their ends.

17. The actuator of claim 16 in which the centers of the thermal half-beams have widths that are about twice those of the ends of the thermal half-beams.

18. The actuator of claim 15 in which the thermal half-beams are tapered from their centers toward their ends.

19. The actuator of claim 1 further including an elongate floating cold beam that is transverse to the length of the in-plane shuttle, the floating cold beam being coupled at one end to the in-plane shuttle and at another end to the substrate, and the floating cold beam being wider along a central region than at the cold beam ends.

20. A thermal microelectrical mechanical actuator, comprising:

a planar substrate with a pair of anchors secured thereto;

plural elongated thermal half-beams each have a base end secured to one of the anchors and a distal end secured to an in-plane shuttle having a length, the thermal half-beams having base ends secured to the pair of anchors being generally parallel to each other;

an elongate floating cold beam that is transverse to the length of the in-plane shuttle, the floating cold beam being coupled at one end to the in-plane shuttle and at another end to the substrate; and

electrical couplings to direct electrical current through the thermal half beams via the anchors to impart thermal expansion of the thermal half-beams and motion of their distal ends.

21. The actuator of claim 20 in which the in-plane shuttle has a length and two sides along its length and the first and second anchors are positioned to one side of the in-plane shuttle.

22. The actuator of claim 20 in which the thermal half-beams have more mass near their centers than at their ends.

23. The actuator of claim 20 in which the thermal half-beams are wider near their centers than at their ends.

24. The actuator of claim 23 in which the centers of the thermal half-beams have widths that are about twice those of the ends of the thermal half-beams.

25. The actuator of claim 23 in which the floating cold beam is wider along a central region than at the cold beam ends.

25. The actuator of claim 20 in which the thermal half-beams are tapered from their centers toward their ends.

26. The actuator of claim 20 in which each thermal half-beam is secured between its anchor and the in-plane shuttle at a non-orthogonal bias angle.

27. The actuator of claim 20 in which the in-plane shuttle is generally in-plane with the thermal half beams.

28. The actuator of claim 20 further including an alignment structure that is secured to the substrate and slidably engages the in-plane shuttle to constrain it to move generally parallel to the substrate.

29. The actuator of claim 20 in which the in-plane shuttle further includes one or more dimple bearings that project from the in-plane shuttle toward the substrate.

30. The actuator of claim 20 in which the thermal half-beams are formed of a material with a positive thermal coefficient of expansion.

31. The actuator of claim 20 in which the floating cold beam is wider along a central region than at the cold beam ends.